



Reference Document: Antimicrobial Interventions for Beef

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This project was funded by beef and veal producers and importers through their \$1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

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Antimicrobial Interventions for Beef

Microbial contamination of beef carcasses and raw meat products may occur during harvesting and subsequent processing. Throughout the process, contamination may be introduced onto the edible product from the hide, gastrointestinal tract, workers, and the environment. The beef industry acknowledges that microbial contamination may occur; however, it has taken multiple actions to reduce the potential for contamination. And it has incorporated, scientifically proven antimicrobial interventions that can be applied individually or in combination with other treatment to reduce the pathogens on the carcass surfaces.

This document provides information on the commonly applied interventions. The document provides scientific references that are available for the different interventions. For some interventions, USDA's Food Safety and Inspection Service has defined limits for use and labeling requirements, and these are also provided.

The reference list at the end of the document provides links to the journal article for those that are available electronically. If you need additional information or assistance in obtaining an article, please call 979-862-3643.

Note: This document will be updated with new information as additional scientific studies are identified or conducted. If you are aware of additional research that should be included or find errors in the information provide, please let us know and the document will be revised.

Hot Water Wash

Product(s): Applied to beef carcasses; heads

Amount approved for use: Not applicable

Labeling Requirements: Not applicable

Scientific References:

Kalchayanand, et al., 2008.

- Hot water was applied to bovine heads for 12 and 26 seconds at $74 \pm 2^\circ\text{C}$ using a commercial spray cabinet.
- Achieved a 2.99 log reduction when applied for 12 seconds; and a 3.55 log reduction when applied for 26 seconds.

Algino, R.J. 2007

- This study was conducted in 22 very small commercial facilities in Wisconsin.
- The hot water intervention consisted of either washing the carcass with $\geq 65.56^\circ\text{C}$ (150°F) water using a low-pressure spray nozzle or spraying $\geq 48.89^\circ\text{C}$ (120°F) water at ≥ 6894.76 kPa (1000 psi) using a pressure washer prior to chilling. Hot water was applied using a hand-held nozzle.
- There was no significant difference ($P > 0.10$) between intervention treatments, and all treatments caused significant reductions ($P < 0.10$) in indicator organisms.

Bosilevac, Joseph M. 2006.

- A commercial hot water carcass wash cabinet applying 74°C (165°F) water for 5.5 s reduced both aerobic plate counts and *Enterobacteriaceae* counts by 2.7 log CFU/100 cm² on pre-evisceration carcasses.
- A commercial lactic acid spray cabinet that applied 2% L-lactic acid at approximately 42°C (105 to 110°F) to pre-evisceration carcasses reduced aerobic plate counts by 1.6 log CFU/100 cm² and *Enterobacteriaceae* counts by 1.0 log CFU/100 cm². When the two cabinets were in use sequentially, i.e., hot water followed by lactic acid, aerobic plate counts were reduced by 2.2 log CFU/100 cm² and *Enterobacteriaceae* counts were reduced by 2.5 log CFU/100 cm².
- Hot water treatments reduced *Escherichia coli* O157:H7 prevalence by 81%, and lactic acid treatments reduced *E. coli* O157:H7 prevalence by 35%, but the two treatments in combination produced a 79% reduction in *E. coli* O157:H7, a result that was no better than that achieved with hot water alone.

Castillo et al., 1998

- High-pressure water wash at 35°C or trim, alone and combined with sanitizing treatments, such as hot water (95°C at the source), warm (55°C) 2% lactic acid spray, and combinations of these two sanitizing methods, were compared for their effectiveness in reducing *Salmonella typhimurium*, *Escherichia coli* O157:H7, aerobic plate counts, *Enterobacteriaceae*, total coliforms,

thermotolerant coliforms, and generic *E. coli* on hot beef carcass surface areas.

- The different combined treatments had higher log reductions than independent treatments.
- The range for mean log reductions: hot water was from 4.0 to >4.8 log CFU/cm², by lactic acid spray was from 4.6 to >4.9 log CFU/cm², by hot water followed by lactic acid spray was from 4.5 to >4.9 log CFU/cm², and by lactic acid spray followed by hot water was from 4.4 to >4.6 log CFU/cm², for *S. typhimurium* and *E. coli* O157:H7.

Castillo et al., 1998a

- Hot water treatment of beef carcass surfaces for reduction of *Escherichia coli* O157:H7, *Salmonella typhimurium*, and various indicator organisms was studied.
- Inoculated carcass surfaces were exposed to a carcass water wash or a water wash followed by hot water spray (95°C).
- All treatments significantly reduced levels of pathogens. Treatments including hot water sprays provided mean reductions of initial counts for *E. coli* O157:H7 and *S. typhimurium* of 3.7 and 3.8 log, and APC reductions of 2.9 log.

Acidified sodium chlorite

Product(s): Meat carcasses, parts, and organs
Processed, comminuted, or formed meat food products (including RTE0
Poultry carcasses and parts

Amount approved for use: 500 to 1200 ppm in combination with any GRAS acid at a level sufficient to achieve a pH of 2.3 to 2.9 in accordance with 21 CFR 173.325 (Note: The pH depends on the type of meat or poultry product)

Labeling Requirements: None under the accepted conditions of use

And:

Product(s): Red meat, red meat parts and organs, and on processed comminuted, formed meat products (including RTE)

Amount approved for use: Applied as a spray or dip, the additive is produced by mixing an aqueous solution of sodium chlorite with any GRAS acid to achieve a pH in the range of 2.2 to 3.0, then further diluting this solution with a pH elevating agent such that the resultant sodium chlorite concentration does not exceed 1200 ppm, and the chlorine dioxide concentration does not exceed 30 ppm. The pH of the solution is between 5.0 and 7.5.

Labeling Requirements: None under the accepted conditions of use.

Scientific References:

Lim et al., 2007

- Applied ASC to cooked roast beef for *E. coli* O157:H7, LM, and *S. aureus* control.

- 0.12% ASC applied as a spray for 0 and 10 day treatments
- Effective as processing aid.

Beverly et al., 2006

- Applied ASC to cooked roast beef for LM control
- ASC applied at 250, 500, 750, or 1,000 ppm for 0, 7, 14, 21, 28 day treatments
- Effective as processing aid.

Gill et al., 2004

- 0.16% acidified sodium chlorite was used as a spray to control natural flora of the distal surfaces of pieces of brisket from chilled beef carcasses
- Acidified sodium chlorite had little effect on the number of aerobes, coliforms, or *E. coli* on the meat
-

Castillo et al., 1999

- Phosphoric acid-activated acidified sodium chloride (PASC) and citric acid-activated sodium chlorite (CASC) were applied at room temperature to beef carcass surfaces inoculated with *E. coli* O157:H7 and *Salmonella* Typhimurium.
- Pathogens were reduced by 3.8 to 3.9 log cycles by water wash followed by PASC spray and by 4.5 to 4.6 log cycles by water wash followed by CASC spray.

Lactic Acid

Products: Livestock carcasses prior to fabrication (i.e., pre-and post-chill), offal, and variety meats

Amount Approved for Use: Up to 5 percent lactic acid solution

Labeling: None under the accepted conditions of use (1)

Scientific references:

King et al., 2005

- 2% lactic acid was applied to beef carcass surfaces to control *E. coli* O157:H7 and *S. Typhimurium*.
- This treatment reduced counts of these microorganisms entering the chilling cooler and prevented growth during the chilling period.
- 2% lactic acid is effective as a carcass wash.

Castillo, et al., 2001

- 4% L-lactic acid was applied to chilled beef carcasses.
- Carcasses were treated during slaughter with hot water and lactic acid.
- The acid solution was 55°C at the source.
- Log reductions were reported in APC, coliform, and *E. coli* counts.

Castillo et al., 1998

- High-pressure water wash at 35°C or trim, alone and combined with sanitizing treatments, such as hot water (95°C at the source), warm (55°C) 2% lactic acid spray, and combinations of these two sanitizing methods, were compared for their effectiveness in reducing *Salmonella typhimurium*, *Escherichia coli* O157:H7, aerobic plate counts, *Enterobacteriaceae*, total coliforms, thermotolerant coliforms, and generic *E. coli* on hot beef carcass surface areas.
- The different combined treatments had higher log reductions than independent treatments.
- The range for mean log reductions: hot water was from 4.0 to >4.8 log CFU/cm², by lactic acid spray was from 4.6 to >4.9 log CFU/cm², by hot water followed by lactic acid spray was from 4.5 to >4.9 log CFU/cm², and by lactic acid spray followed by hot water was from 4.4 to >4.6 log CFU/cm², for *S. typhimurium* and *E. coli* O157:H7.

Dorsa et al., 1997

- 3.0% lactic acid applied as a spray on beef carcasses
- *E. coli* O157:H7, *Listeria innocua*, and *Clostridium sporogenes* tracked through 21 days of storage after treatments were applied
- Effective as a carcass wash

Hardin, et al., 1995

- Hot carcass surface area was inoculated with *E. coli* O157:H7 or *Salmonella typhimurium*
- Trimming, water wash, lactic acid, and acetic acid treatments were evaluated.
- Washing followed by 2% lactic acid or acetic acid spray was more effective than trimming or washing alone.
- Lactic acid provided a greater reduction of *E. coli* O157:H7 than acetic acid.

Hamby et al., 1987

- 1.0% lactic acid was applied as a spray on beef carcasses
- Application of lactic acid as an intermittent spray of beef sides significantly reduced APC of cuts that were stored for 28 days. Single lactic acid spray of beef sides also reduced APCs of some of the cuts significantly.
- Effective as a carcass wash

Lactic Acid

Products: Beef and pork sub-primals and trimmings

Amount approved for use: 2 percent to 5 percent solution of lactic acid not to exceed 55°C

Labeling requirements: None under the accepted conditions of use

Scientific References:

Heller et al., 2007

- 2.5%, 5.0% and 2% activated lactoferrin followed by warm 5.0% lactic acid was applied to beef subprimal cuts to control *E. coli* O157:H7
- This study shows that if populations of *E. coli* O157:H7 are low and that interventions are applied before mechanical tenderization can effectively reduce the transfer of low concentrations of *E. coli* O157:H7 to the interior of beef subprimal cuts

Gill et al., 2004

- 2% and 4% lactic acid was applied as a spray to beef trimmings to control natural flora of the distal surfaces of pieces of brisket from chilled beef carcasses
- Both treatments showed reductions on aerobes, coliforms, or *E. coli* although 4% lactic acid was more effective

Castillo et al., 2001a

- Prechill decontamination treatments were applied to the hot product, and resulted in pathogen reductions.
- 4% L-lactic acid at 55°C was applied for 30 seconds to chilled outside rounds.
- Postchill acid treatment resulted in an additional reduction in both *E. coli* O157:H7 and *Salmonella* Typhimurium.
- Pathogen levels were lower in ground beef produced from products that received the prechill and postchill acid spray.

Prasai et al., 1997

- 1.5% lactic acid applied as a spray on beef subprimals
- After a lactic acid treatment and 14, 28, 56, 84, and 126 days of vacuum storage improved the microbiological quality of meat compared to the control.

Kotula et al., 1994

- 1.2% lactic acid applied as a spray on retail beef cuts
- After treatment of retail beef total CFU and *E. coli* numbers were reduced
- Treated beef that was stored 3-9 days observed a larger log reduction when compared to non-treated control samples

Lactic Acid

Products: Beef heads and tongues

Amount approved for use: A 2.0 to 2.8 percent solution applied to brushes in a washer cabinet system used to clean beef heads and tongues

Labeling requirements: None under the accepted conditions of use

Scientific References:

Kalchayanand, et al., 2008.

- DL-lactic acid was applied to bovine heads using a model spray-washing cabinet.
- Achieved a 1.52 log reduction for *E. coli* O157:H7

Lactoferrin

Products: Beef carcasses and parts

Amounts approved for use: At up to 2 percent of a water-based antimicrobial spray; GRAS Notice No. 000067

Labeling requirements: Listed by common or usual name in the ingredients statement

Scientific References:

Heller et al., 2007

- 2% activated lactoferrin followed by warm 5.0% lactic acid was applied to beef subprimal cuts to control *E. coli* O157:H7
- This study shows that if populations of *E. coli* O157:H7 are low and that interventions are applied before mechanical tenderization can effectively reduce the transfer of low concentrations of *E. coli* O157:H7 to the interior of beef subprimal cuts

Organic Acids (i.e., lactic acetic, and citric acid)

Product(s): As part of a carcass wash applied pre-chill

Amounts approved for use: At up to 2.5 percent of a solution; FSIS Notice 49-94

Labeling requirements: None under the accepted conditions of use

Scientific Support:

Arthur et al, 2008

- Beef flank sections were inoculated and treated prior to chilling
- 2% Acetic acid was applied and *E. coli* O157:H7 was reduced by 0.65 log CFU/cm² and Salmonella was reduced by 0.87 to 0.91 log CFU/cm²
- FreshFX was applied

Algino, R.J. 2007

- The interventions studied were dry-aging, low-pressure hot-water spray, high-pressure hot-water spray, 2.5% acetic acid spray, and Fresh Bloom™ (a mix of citric acid, ascorbic acid, and erythorbic acid) spray.
- Sprays were applied using a hand-held nozzle (hot water) or a pump-type sprayer (acid).

- There was no significant difference ($P > 0.10$) between intervention treatments and all treatments caused significant reductions ($P < 0.10$) in indicator organisms.

Tinney et al., 1997

- Beef treated with 2% acetic acid spray, pulsed-power electricity, pulsed-power electricity with a spray of sterile deionized water, and a combination of acetic acid spray and pulsed-power electricity.
- Acetic acid spray and acetic acid spray and pulsed-power electricity treatments significantly reduced the incidence of *Escherichia coli* O157.
- Acetic acid spray with and without pulsed-power electricity caused a 1-log CFU/cm² reduction in *S. typhimurium*.

Podolak et al., 1995

- Beef was dipped in fumaric, lactic, and acetic acid to control *E. coli* O157:H7 and *Listeria monocytogenes*.
- Also combinations of these acids were applied as a dip.
- Fumaric acid at concentrations of 1.0% and 1.5% was more effective than any of the combined solutions of acids.
- Fumaric was most effective followed by lactic and acetic acids

Dickson 1992

- Beef tissue surfaces treated with 2% acetic acid to control *S. typhimurium*
- More effective on lean tissue than on fat tissues

Anderson et al., 1989

- Beef cores were dipped in 0, 1, 2, 3% acetic acid at 25, 40, 55, 70°C
- Most effective treatment was 3% acetic acid at 70°C
- Most effective on total aerobic plate count followed by *Enterobacteriaceae* count, and *E. coli* was least affected. *S. Typhimurium* counts were affected least by temperature.

Peroxyacetic acid, octanoic acid, acetic acid, hydrogen peroxide, peroxyoctanoic acid, and 1- hydroxyethylidene-1,1- diphosphonic acid (HEDP)

Product(s): Meat and poultry carcasses, parts, trim and organs

Amounts approved for use: Maximum concentrations for meat carcasses, parts, and organs: Peroxyacetic acids 220 ppm, hydrogen peroxide 75 ppm; Maximum concentrations for poultry carcasses, parts, and organs: Peroxyacetic acids 220 ppm, hydrogen peroxide 110 ppm, HEDP 13 ppm; 21 CFR 173.370

Labeling requirements: None under the accepted conditions of use

Scientific references:

Ellebracht et al., 2005

- Beef trimmings were dipped in 200, 500, and 1000 ppm of peroxyacetic acid to control *E. coli* O157:H7 and *S. typhimurium*.
- Even when exceeding the approved amount for use of peroxyacetic acid lactic acid still showed larger log reductions for *E. coli* O157:H7 and *S. typhimurium*.
- Peroxyacetic acid is not as effective as lactic acid on beef trimmings.

King et al., 2005

- 200 ppm Peroxyacetic acid applied to chilled carcasses to control *E. coli* O157:H7 and *S. typhimurium*
- Concentrations up to 600 ppm of Peroxyacetic acid applied to chilled carcasses had no effect on these microorganisms.

Gill et al., 2004

- 0.02% peroxyacetic acid was applied as a spray to control natural flora of the distal surfaces of pieces of brisket from chilled beef carcasses
- Peroxyacetic acid had little effect on the number of aerobes, coliforms, or *E. coli* on the meat

Pohlman et al., 2002

- 5% acetic acid followed by 0.5% cetylpyridinium chloride was applied by tumbling to beef trimmings to control *E. coli* and *S. typhimurium*
- This treatment was effective on beef trimmings.

Ozone

Products: All meat and poultry products

Amount approved for use: In accordance with current industry standards of good manufacturing practice; 21 CFR 173.368

Labeling requirements: None under the accepted conditions of use

Scientific references:

Castillo, et al., 2003

- Aqueous ozone solution (80 lb/in² at 28°C), containing 95 mg of ozone per liter was applied to hot carcass surfaces.
- Reductions of *E. coli* O157:H7 and Salmonella Typhimurium achieved with the ozone treatment were not different than reductions obtained with water wash.

Stivarius et al., 2002

- Beef trimmings were dipped in 1% ozonated water to control *E. coli* and *S. typhimurium*.
- Ozone is effective in controlling *E. coli* and *S. typhimurium* in beef trimmings.

Calcium hypochlorite

Product(s): Red meat carcasses down to a quarter of a carcass

Amounts approved for use: Applied as a spray at a level not to exceed 50 ppm calculated as free available chlorine

Labeling requirements: None under the accepted conditions of use

Scientific references:

Emswiller et al., 1976

- 8,500 mL of calcium hypochlorite was applied to beef forequarters as a spray at 0, 50, 100, 200, 400 ppm
- Although calcium hypochlorite only slightly reduced the total aerobic counts at 50 ppm there was about a 1 log reduction at 100, 200, and 400 ppm

Chlorine dioxide

Products: Red meat, red meat parts and organs; processed, comminuted, or formed meat food products

Amounts Approved: Applied as a spray or dip at a level not to exceed 3 ppm residual chlorine dioxide as determined by Method 4500-ClO₂ E in the “Standard Methods for the Examination of Water and Wastewater,” 18th ed., 1992, or an equivalent method

Labeling requirements: None under the accepted conditions of use

Scientific references:

Stivarius et al., 2002

- Chlorine dioxide sprayed at 200 ppm was effective against *E. coli* and *S. typhimurium* on beef trimmings
- Beef trimmings were packaged and sampled at 0, 1, 2, 3, and 7 days

Emswiller et al., 1976

- 8,500 mL of chlorine dioxide was applied to beef forequarters as a spray at 0, 50, 100, 200, 400 ppm
- Chlorine dioxide did not significantly reduce total bacterial counts, but was most effective at 50 and 400

Electrolytically generated hypochlorous acid

Products: Red meat carcasses down to a quarter of a carcass

Amounts approved: Applied as a spray at a level not to exceed 50 ppm calculated as free available chlorine

Labeling requirements: None under the accepted conditions of use

Scientific references:

Emswiller et al., 1976

- 8,500 mL of electrolytically generated hypochlorous acid was applied to beef forequarters as a spray at 0, 50, 100, 200, 400 ppm
- At 50 ppm there was only a slight reduction in total aerobes and psychotrophic bacteria
- At 100, 200, and 400 ppm total aerobes and psychotrophic bacteria were significantly reduced

Anhydrous ammonia

Product(s): Lean finely textured beef which is subsequently quick chilled to 28°F and mechanically “stressed”

Amount approved: In accordance with current industry standards of good manufacturing practice

Labeling requirements: None under the accepted conditions of use.

Scientific references:

Not able to locate any journal articles on anhydrous ammonia.

References:

(Most of the references include a link to the journal. Just click on the reference, and if it is available electronically, you will be taken to the journal or to the article. If the link does not work, please let us know.)

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